ACTUAL 2007 STPM

PHYSICS EXAMINATION PAPER

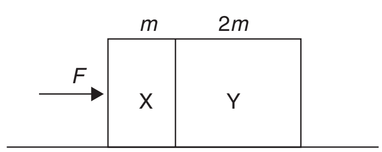
PAPER 1

Time: 1h 45 min

1. The tensile strength of a wire is the maximum stress on the wire just before it breaks. What is the dimension of tensile strength?

   A $ML^{-1}T^{-1}$ **C** MLT^{-1}
   B $ML^{-1}T^{-2}$ **D** MLT^{-2}

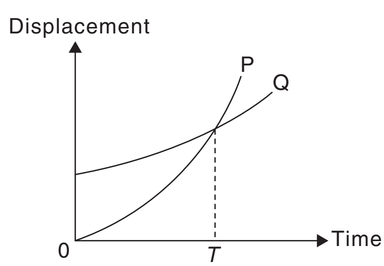
2. The figure shows two blocks X and Y, of masses m and $2m$ respectively, placed on a smooth horizontal surface.



   If the blocks are accelerated by a force F, the force exerted on block X by block Y is

   A $\frac{1}{3}F$ **C** $\frac{2}{3}F$
   B $\frac{1}{2}F$ **D** F

3. The figure shows the displacement–time graphs of two vehicles P and Q.



   Which statement describes the motion of the two vehicles at time T?

   A P and Q are momentarily at rest.
   B The speeds of P and Q are the same.
   C The speed of P is greater than the speed of Q.
   D The accelerations of P and Q are equal to zero.

4. What is the energy change that occurs when a ball rolls down an inclined plane without slipping?

   A Potential energy → translational kinetic energy
   B Potential energy → rotational kinetic energy
   C Potential energy → translational kinetic energy + rotational kinetic energy
   D Potential energy → translational kinetic energy + work against friction

5. A car of mass 1250 kg accelerates from 0 to 100 km h^{-1} in 4.0 s. The average power of the car is

   A 121 kW
   B 341 kW
   C 484 kW
   D 681 kW

6. For a particle moving in a circle with a constant speed, the physical quantity which is always constant is

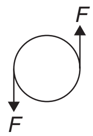
   A displacement
   B acceleration
   C linear momentum
   D angular momentum

7. A firework in the shape of a disc can spin freely about its axis. The radius of the disc is 2.0 cm and its moment of inertia is 1.0×10^{-6} kg m^2. When the firework is ignited, gas is ejected from the rim in the tangential direction at a constant speed of 50 m s^{-1} relative to the rim. The gas is ejected at a rate of 1.0×10^{-5} kg s^{-1}. The angular velocity of the disc after 10 s of burning is

   A 10 rad s^{-1}
   B 50 rad s^{-1}
   C 100 rad s^{-1}
   D 200 rad s^{-1}

8. Which figure shows that coplanar forces, each of magnitude F acting on a disc, are in equilibrium?

A



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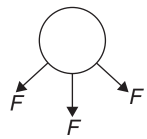

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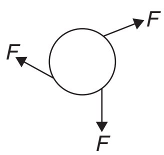

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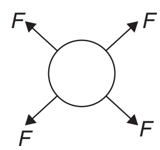
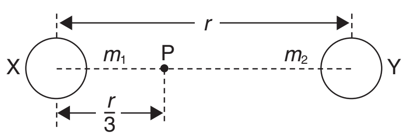


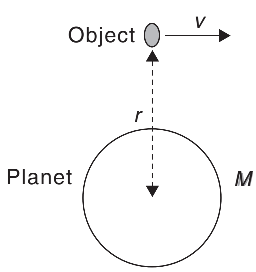
9. The figure shows two stars X and Y of masses m_1 and m_2 respectively and separated by a distance r.



If the gravitational field strength at point P at distance $\frac{r}{3}$ from X is zero, the ratio of m_1 to m_2 is

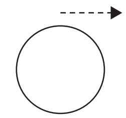
A 1 : 4
B 1 : 2
C 2 : 1
D 4 : 1

10. The figure shows an object in space moving near a planet of mass M.



The shortest distance between the object and the planet is r. The speed v of the object at the nearest position is $1.5\sqrt{\frac{GM}{r}}$, where G is the gravitational constant. Which figure shows the correct trajectory of the object?

A



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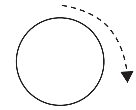

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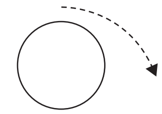

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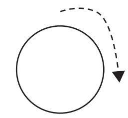


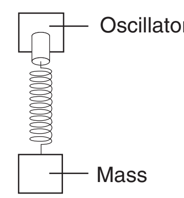
11. The equation of motion of an object performing simple harmonic motion is given by

$$x = 5 \sin \frac{\pi}{6}t,$$

where x is the displacement in metres and t is the time in seconds. When $t = 1$ s, the speed of the object is

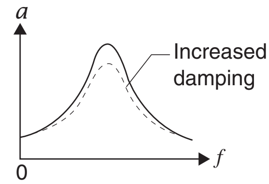
A 2.3 m s^{-1} **C** 4.3 m s^{-1}
B 2.6 m s^{-1} **D** 4.6 m s^{-1}

12. The figure shows a mass attached to a spring made to oscillate vertically by an oscillator.



If the damping is slightly increased, which graph shows the variation of amplitude a with frequency f of the oscillation?

A



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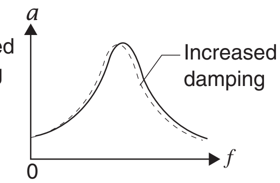

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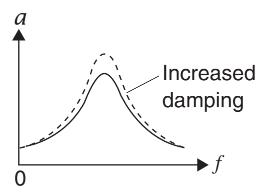

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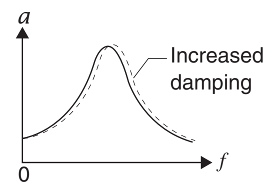
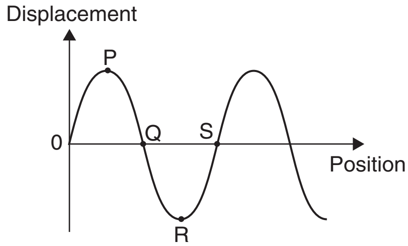


13. What is the phase difference between two points separated by a distance of 3.0 cm in a wave of wavelength 5.0 cm?

A 0.6 rad **C** 1.9 rad
B 1.7 rad **D** 3.8 rad

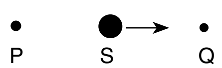
14. The graph shows the displacement of the particles in a rope caused by a travelling wave at a particular time.



Which statement is not true of the motion of the particles in the rope?

A The speed of the particle at P is maximum.
B The acceleration of the particle at Q is zero.
C The energy of the particle at R is entirely potential energy.
D The energy of the particle at S is entirely kinetic energy.

15. The figure shows a sound source S moving away from observer P towards observer Q.



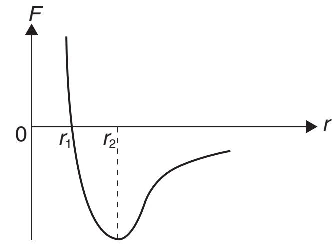
What is the effect of the motion on the wavelength of the sound received by P and by Q?

	P	*Q*
A	Increases	Decreases
B	Increases	No change
C	Decreases	Increases
D	No change	Decreases

16. A person can hear a sound of intensity 1.0×10^{-11} W m^{-2}. When a hearing aid is used, the sound level increases by 35 dB. What is the new intensity of the sound heard?

A 3.50×10^{-11} W m^{-2}
B 3.50×10^{-10} W m^{-2}
C 3.16×10^{-9} W m^{-2}
D 3.16×10^{-8} W m^{-2}

17. The graph shows the variation of the interatomic force F with the separation r between two atoms.



Which statement is **not** true of the graph?

A Hooke's law is true around r_1.
B The equilibrium separation is r_2.
C The force is an attractive force when $r > r_1$.
D The force is an attractive force when $r > r_2$.

18. When a metal wire is stretched over a limit, it undergoes plastic deformation. Which statement is true of plastic deformation?

A Stress is proportional to strain.
B The metal is not a crystalline solid.
C The atomic planes slide over each other.
D The atoms are displaced a little from their equilibrium positions.

19. A cylinder of volume 0.09 m^3 contains an ideal gas at 100 °C and 8×10^4 Pa. If the mass of one mole of the gas is 0.034 kg, the r.m.s. speed of the gas molecules is

A 2.71×10^2 m s^{-1} **C** 7.33×10^4 m s^{-1}
B 5.23×10^2 m s^{-1} **D** 2.73×10^5 m s^{-1}

20. At what temperature is the r.m.s. speed of oxygen molecules the same as that of helium molecules at 300 K?
[Relative molecular mass of oxygen = 32, relative molecular mass of helium = 4]

A 38 K **C** 1440 K
B 849 K **D** 2400 K

21. The work done to adiabatically compress one mole of a diatomic gas is 50 J. What is the temperature rise of the gas?

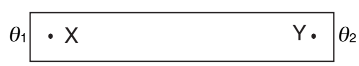
A 0 K **C** 2.41 K
B 1.72 K **D** 4.10 K

22. Which statement is true of an adiabatic process?

A Boyle's law is obeyed.
B The temperature is always constant.
C The internal energy always increases.
D No heat is transferred into or out of the system.

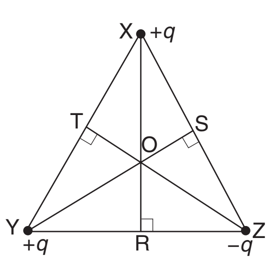
23. In an experiment to measure the thermal conductivity of a good conductor, a long test sample is used so that
A the heat loss can be neglected
B the steady state is easily achieved
C the heat flow is parallel throughout the sample
D the temperature difference between the two ends of the sample is sufficiently large

24. The figure shows a uniform metal rod which is not insulated.



Heat flows through the rod in a steady state, and the temperatures at the ends of the rod are θ_1 and θ_2, where $\theta_1 > \theta_2$. Which statement is true of the two positions X and Y on the rod as shown?
A No heat is lost to the surroundings at the area between X and Y.
B The rate of heat loss to the surroundings at X is greater than that at Y.
C The rates of heat flow at X and Y are the same.
D The temperature gradients at X and Y are the same.

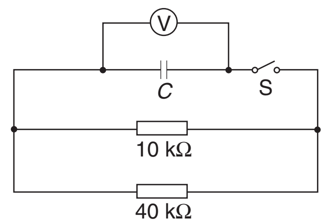
25. The figure shows three point charges $+q$, $+q$ and $-q$ at the vertices X, Y and Z respectively of an equilateral triangle.



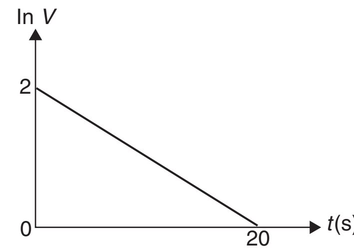
The electric field strength at the centroid O of the triangle is in the direction of
A OS　　**C** OY
B OT　　**D** OZ

26. The work done to bring two point charges $+q$ and $-q$ from infinity to separation r is
A $\dfrac{q^2}{4\pi\varepsilon_0 r}$　　**C** $\dfrac{q^2}{2\pi\varepsilon_0 r}$
B $-\dfrac{q^2}{4\pi\varepsilon_0 r}$　　**D** $-\dfrac{q^2}{2\pi\varepsilon_0 r}$

27. The circuit diagram shows a 10 kΩ resistor and a 40 kΩ resistor connected across a charged capacitor C.



After switch S is closed, the potential difference V across the capacitor varies with time t. The graph of ln V against t is given as follows.

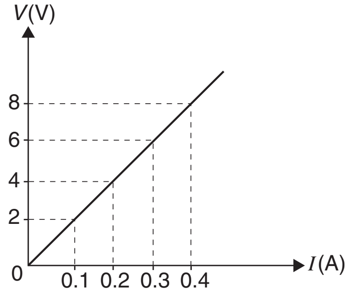


The capacitance of the capacitor is
A 1.25×10^{-5} F　　**C** 1.25×10^{-3} F
B 2.00×10^{-4} F　　**D** 2.50×10^{-3} F

28. A parallel-plate capacitor is charged by a battery. The space between the plates is then completely filled with a material of dielectric constant ε_r while the battery remains connected. What is the ratio of the energy stored after the material is inserted to the energy stored before the material is inserted?
A $1: \varepsilon_r^2$　　**C** $\varepsilon_r: 1$
B $1: \varepsilon_r$　　**D** $\varepsilon_r^2: 1$

29. A lamp lights up immediately when the switch in a circuit is closed, although the drift velocity of electrons is small. This is because
A the current flowing in the circuit is large
B the potential difference supplied in the circuit is large
C the random velocity of the electrons is large
D all the free electrons drift simultaneously in the circuit

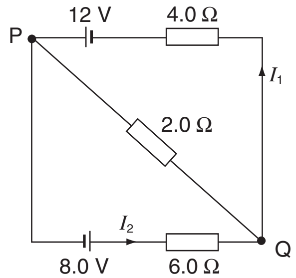
30. The graph shows the variation of potential difference V across a resistor with current I flowing through it.



When the current is 0.23 A, the power supplied to the resistor is

A 0.53 W **C** 2.12 W
B 1.06 W **D** 4.23 W

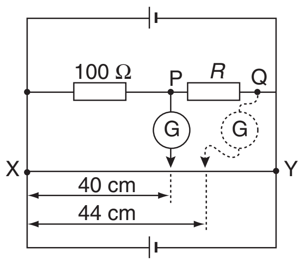
31. The figure shows a circuit consisting of two batteries and three resistors.



If I_1 and I_2 are 2.56 A and 1.64 A respectively, the potential difference between points P and Q is

A 1.8 V **C** 9.8 V
B 4.0 V **D** 20 V

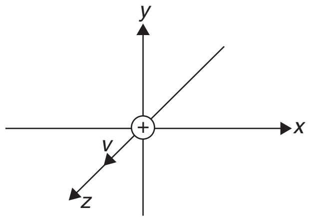
32. The figure shows a circuit, where XY is a uniform wire.



When the galvanometer is connected at point P and then at point Q, the balanced lengths are 40 cm and 44 cm respectively. The value of R is

A 10 Ω **C** 110 Ω
B 91 Ω **D** 400 Ω

33. The figure shows a positive charge moving through a uniform magnetic field at velocity v in the positive z-direction.



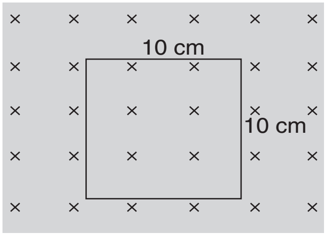
If the magnetic field is in the positive x-direction, the magnetic force acting on the positive charge is in

A the positive x-direction
B the negative x-direction
C the positive y-direction
D the negative y-direction

34. Hall effect **cannot** be used to measure

A the charge density
B the magnetic flux density
C the mass of charge carriers
D the type of charge carriers

35. The figure shows a square coil of sides 10 cm and resistance 2.00 Ω placed in a uniform magnetic field of 10.0 T directed perpendicularly to the coil.



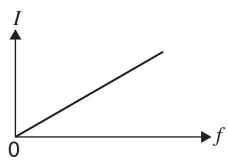
If the magnetic field is reduced to zero at a constant rate in 40 ms, what are the magnitude and direction of the induced current?

	Magnitude	*Direction*
A	1.25 A	Clockwise
B	1.25 A	Anticlockwise
C	2.50 A	Clockwise
D	2.50 A	Anticlockwise

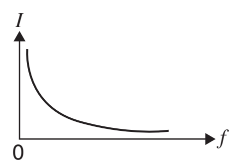
36. Which statement is not true of the back e.m.f. of an electric motor?
  A The back e.m.f. opposes the applied voltage.
  B The back e.m.f. is caused by electromagnetic induction.
  C The back e.m.f. helps increase the magnitude of the current flowing through the coil of the motor.
  D The magnitude of the back e.m.f. increases if the speed of rotation of the coil of the motor is increased.

37. An a.c. power supply with a constant r.m.s. voltage and variable frequency is connected in series to a pure inductor. Which graph shows the variation of the r.m.s. current I with the frequency f?

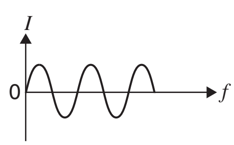
A



C



B



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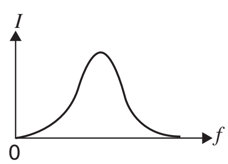
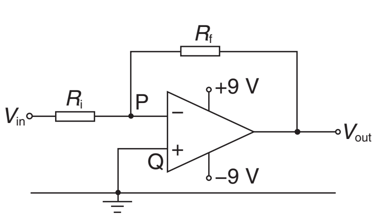


38. The alternating voltage supplied to a 200 μF capacitor is given by $V = 5 \sin 300t$, where V is in volts and t is in seconds. The maximum current in the circuit is
  A 0 A **C** 0.30 A
  B 0.21 A **D** 83 A

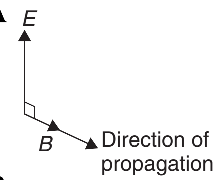
39. The figure shows a circuit of an inverting amplifier.



An input voltage of +2 V produces an output voltage of –8 V. Which statement about the circuit is **not** true?
  A The value of $\frac{R_f}{R_i}$ is 4.
  B The voltage gain is –4.
  C When the input voltage is –1 V, the output voltage is +4 V.
  D When the input voltage is 2 V, the potential at point P is 2 V.

40. Which figure shows the correct directions of the magnetic field B and electric field E in relation to the direction of propagation of an electromagnetic wave?

A



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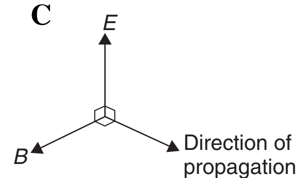

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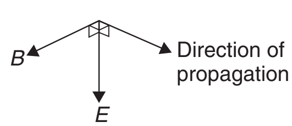

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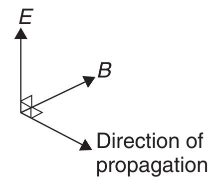
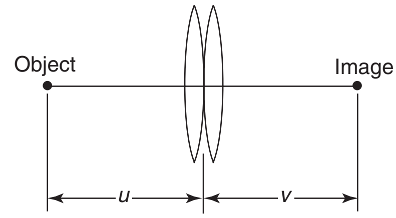


41. Which statement is true of an electromagnetic spectrum?
  A Radio waves are longitudinal waves.
  B Only the visible spectrum can be plane-polarised.
  C X-rays travel at a higher speed than ultraviolet waves.
  D Gamma rays have a higher frequency than infrared waves.

42. The figure shows two lenses of focal lengths f_1 and f_2 placed in contact with each other.



If the object distance is u and the image distance is v, then $\frac{1}{u} + \frac{1}{v}$ equals
  A $\frac{1}{f_1} + \frac{1}{f_2}$ **C** $\frac{1}{f_1 + f_2}$
  B $\frac{1}{f_1} - \frac{1}{f_2}$ **D** $\frac{1}{f_1 - f_2}$

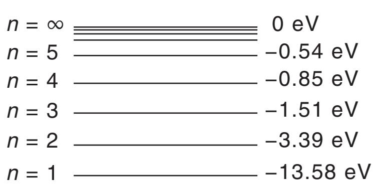
43. A diffraction grating with 2400 lines per centimetre is used to produce a diffraction pattern that is recorded by a detector. The first-order fringe is 8.94 cm from the central fringe. If the distance between the grating and the detector is 0.625 m, what is the wavelength of the electromagnetic wave used?

A 295 nm   **C** 1180 nm
B 590 nm   **D** 1190 nm

44. An experiment is performed to show the photoelectric effect. The frequency of the light used is kept constant while the intensity is increased. Which quantity will increase?

A The momentum of the photoelectrons
B The emission rate of the photoelectrons
C The maximum kinetic energy of the photoelectrons
D The minimum de Broglie wavelength of the photoelectrons

45. The figure shows the energy levels of the hydrogen atom.



Which transition produces radiation of wavelength 436 nm?

A $n = 4$ to $n = 1$ **C** $n = 5$ to $n = 1$
B $n = 4$ to $n = 2$ **D** $n = 5$ to $n = 2$

46. In an X-ray tube, the minimum wavelength produced is 4.0×10^{-11} m. If the potential difference between the cathode and anode is decreased to half of the original value, the minimum wavelength becomes

A 2.0×10^{-11} m   **C** 8.0×10^{-11} m
B 4.0×10^{-11} m   **D** 1.6×10^{-10} m

47. Stimulated emission occurs in the laser when a photon P causes the emission of a photon Q. Which statement is true of the photons?

A The phase of P is the same as that of Q.
B The frequency of P is less than that of Q.
C The wavelength of P is less than that of Q.
D The energy of P is more than that of Q.

48. If the masses of the proton, neutron, electron and ${}^{12}_{6}C$ atom are m_p, m_n, m_e and m_c respectively, the mass defect Δm of the nucleus ${}^{12}_{6}C$ is given by

A $\Delta m = 6m_p + 6m_n - m_c$
B $\Delta m = 6m_p + 6m_n - 6m_e - m_c$
C $\Delta m = 6m_p + 6m_n + 6m_e - m_c$
D $\Delta m = 6m_p + 6m_n + 6m_e - 6m_c$

49. A sample consists of 2 g of a radioactive element. The molar mass of the element is 67 g. If the half-life of the element is 78 hours, the activity of the sample after 48 hours is

A 2.7×10^{16} s^{-1}
B 2.9×10^{16} s^{-1}
C 4.4×10^{16} s^{-1}
D 1.0×10^{20} s^{-1}

50. A nuclide decays by emitting x alpha particles and y beta particles to form an isotope of the original nuclide. What are the values of x and y?

	x	y
A	1	2
B	1	4
C	2	1
D	2	2

QUESTION PAPER ENDS

PAPER 2

Time: 2 h 30 min

Section A [40 *marks*]

Answer **all** *questions in this section.*

1. A cylinder of mass 10 kg and radius 0.2 m rolls down an inclined plane of height 1.0 m without slipping from rest. Calculate the linear velocity of the cylinder when it reaches the ground. [4 *marks*]

   [Moment of inertia of a cylinder of mass m and radius r is $\frac{1}{2}mr^2$.]

2. (a) On the same axes, sketch graphs of displacement against time to show underdamped, critically damped and overdamped oscillations. Label your graphs. [3 *marks*]

   (b) What is meant by *resonance* in forced oscillations? [2 *marks*]

3. (a) In each of the following cases, state any change in the interference pattern of a two-slit arrangement.

   (i) One slit is covered by an opaque material. [1 *mark*]

   (ii) The distance between the slits is decreased. [1 *mark*]

   (b) Explain how interference can be used to determine the flatness of lens surface. [2 *marks*]

4. A cylindrical brass rod with Young's modulus 9.7×10^{10} Pa and original diameter 10.0 mm experiences only elastic deformation when a tensile load of 200 N is applied.

   (a) Calculate the stress that produces the deformation. [3 *marks*]

   (b) If the original length of the rod is 0.25 m, calculate the change in the length of the rod. [2 *marks*]

5. A 1.5 μF capacitor and a 2.0 μF capacitor are connected in series across a 24 V source.

   (a) Calculate the equivalent capacitance across the source. [2 *marks*]

   (b) Calculate the charge stored on each capacitor. [2 *marks*]

   (c) If a dielectric is added to each capacitor, explain what happens to the charge stored in each capacitor. [2 *marks*]

6. An ideal solenoid consists of 1000 turns of wire per cm wound around an air-filled cylindrical structure. The solenoid is of 2.0 cm long and cross-sectional area 1.8 cm^2. A current of 2.0 A passes through the wire.

   (a) Calculate the magnetic flux in the solenoid. [3 *marks*]

   (b) Calculate the self-inductance of the solenoid. [2 *marks*]

7. A light beam of wavelength 0.110 nm collides with an atom. After the collision, an electron is emitted with kinetic energy 180 eV.

   (a) Calculate the energy absorbed by the atom. [3 *marks*]

   (b) Calculate the velocity of the electron emitted. [2 *marks*]

8. In a nuclear reactor, a very slow moving neutron is absorbed by a stationary boron atom. The equation for the nuclear reaction is

$$ {}^{1}_{0}\mathrm{n} + {}^{10}_{5}\mathrm{B} \rightarrow {}^{7}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He} $$

After the reaction, the speed of the helium atom is 9.10×10^6 m s^{-1} and the kinetic energy of the neutron is approximately zero.

[m_n = 1.0087 u, m_B = 10.0130 u, m_{Li} = 7.0160 u, m_{He} = 4.0026 u]

(a) Calculate the kinetic energy of the lithium atom after the reaction. [4 *marks*]

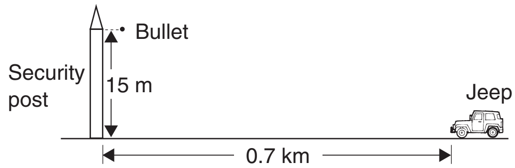
(b) Calculate the reaction energy. [2 *marks*]

Section B [60 *marks*]

Answer any **four** *questions in this section.*

9. (a) An object is projected with initial speed v at angle θ to the horizontal. Derive an equation for the path of the projectile. [3 *marks*]

(b) The figure shows a jeep travelling at a constant speed of 10 m s^{-1} towards a security post.



A security guard holding his rifle 15 m above the ground shoots horizontally when the jeep is 0.7 km from the security post. The bullet of the rifle strikes the jeep. Calculate

(i) the time taken by the bullet to strike the jeep [2 *marks*]

(ii) the distance of the jeep from the security post when it is struck [2 *marks*]

(iii) the initial speed of the bullet [2 *marks*]

(iv) the speed and direction of the bullet when it strikes the jeep. [6 *marks*]

10. (a) What is meant by *Doppler effect*? [2 *marks*]

(b) A toy car with the siren on is approaching a wall at a speed of 2.0 m s^{-1}. The siren produces a sound wave in the form

$$y = 2.5 \times 10^{-5} \sin 2\pi(500t - 1.4x)$$

where x is in metres and t is in seconds. Calculate the speed and frequency of the sound wave. [4 *marks*]

(c) The sound wave in (b) is then reflected from the wall. A detector is fixed on the ground behind the source of the sound wave to detect any frequency changes. Determine

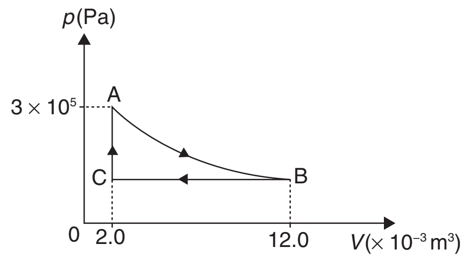
(i) the frequencies detected by the detector [4 *marks*]

(ii) the beat frequency [2 *marks*]

(iii) the equation of the reflected wave [1 *mark*]

(iv) the intensity ratio of the approaching wave to the reflected wave. [2 *marks*]

11. The following is a p–V diagram for a 0.2 mol ideal monatomic gas.



The gas expands isothermally from A to B and is compressed from B to C at constant pressure. It finally undergoes a constant volume process from C to A. Calculate

(a) the temperatures at A, B and C [5 *marks*]
(b) the net work done during the cycle [5 *marks*]
(c) the net heat absorbed by the gas. [5 *marks*]

[For an ideal monatomic gas, $C_V = \frac{3}{2}R$ and $C_p = C_V + R$]

12. (a) A 0.3 μF capacitor is connected to a source of alternating current with output voltage

$$V = 240 \sin 120\pi t$$

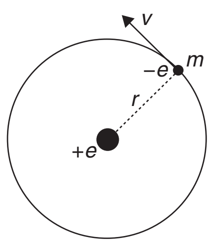
(i) Calculate the reactance of the capacitor. [3 *marks*]
(ii) Determine the r.m.s. current flowing through the capacitor. [3 *marks*]

(b) A rectifier is a device which conducts electric current in one direction only such as a diode.

(i) Describe briefly a full-wave rectifier. [4 *marks*]
(ii) With the aid of diagrams, describe briefly the process of smoothing rectified alternating current voltages. [5 *marks*]

13. (a) State Bohr's postulates for an atom. [2 *marks*]

(b) The figure shows an electron of mass *m* and charge –*e* moving at speed *v* in a circular orbit of radius *r* round a nucleus.



If the force of attraction between the electron and the nucleus provides the centripetal acceleration of the electron, derive an expression for the radius of the n^{th} orbit of the electron. [5 *marks*]

(c) An electron in a Bohr orbit has kinetic energy 8.64×10^{-20} J.

(i) Calculate the speed of the electron. [3 *marks*]
(ii) Determine the allowed orbit. [3 *marks*]
(iii) Calculate the radius of the orbit. [2 *marks*]

14. (a) The bombardment of a beryllium nucleus by an α-particle produces a fundamental particle X, as follows.

$$\alpha + {}^{9}_{4}\text{Be} \longrightarrow {}^{12}_{6}\text{C} + \text{X}$$

(i) Complete the equation above by giving the proton and nucleon numbers to the α-particle and X. [2 *marks*]
(ii) What are the α-particle and X? [2 *marks*]
(iii) State **two** important properties which make X difficult to detect. [2 *marks*]

(b) Determine the equivalent energy in MeV of a mass of 1 u. [5 *marks*]

(c) An element of unknown atomic mass is mixed with ${}^{12}_{6}\text{C}$ atoms in a mass spectrometer.

The radii of curvature of the tracks of the ions of the element and ${}^{12}_{6}\text{C}$ are 26.2 cm and 22.4 cm respectively. What is possibly the element? State any assumption you make. [4 *marks*]

QUESTION PAPER ENDS

Suggested Answers

PAPER 1

1. B: [Tensile strength] = [stress] = $[\frac{F}{A}] = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$

2. C: If a = acceleration, $F = (m + 2m)a = 3ma$,
   force of Y on X = force of X on Y = $(2m)a = \frac{2F}{3}$

3. C: Speed = gradient of graph.
   When $t = T$, gradient of P > gradient of Q.

4. C: Ball has translational and rotational K.E.

5. A: Average power = $\frac{\text{gain in K.E.}}{\text{time}} = \frac{\frac{1}{2}mv^2}{t}$ = 121 kW

6. D: Angular momentum = $I\omega = (mr^2)\omega$ = constant.

7. C: Force produced by the ejected gas, $F = v\frac{dm}{dt}$
   Torque = $Fr = I\alpha$, $\alpha = \left(v\frac{dm}{dt}\right)\left(\frac{r}{I}\right)$
   $= (50)(1.0 \times 10^{-5})\left(\frac{0.020}{1.0 \times 10^{-6}}\right)$ rad s^{-2}
   $= 10$ rad s^{-2}
   Angular velocity after 10 s,
   $= \alpha t = (10)(10)$ rad s^{-1} = 100 rad s^{-1}

8. D: Resultant force = 0,
   resultant torque about centre of disc = 0.

9. A: $E_X = E_Y$, $\frac{Gm_1}{(r/3)^2} = \frac{Gm_2}{(2r/3)^2}$
   $\frac{m_1}{m_2} = \frac{1}{4}$

10. B: For object to move in circular orbit, velocity = $\sqrt{\frac{GM}{r}}$
    Escape speed = $\sqrt{\frac{2GM}{r}}$
    Speed of $1.5\sqrt{\frac{GM}{r}} > \sqrt{\frac{2GM}{r}} > \sqrt{\frac{GM}{r}}$
    Therefore trajectory is as in B.

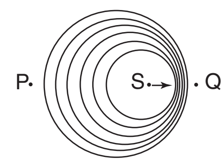
11. A: $x = 5 \sin \frac{\pi}{6}t$
    Speed, $v = \frac{dx}{dt} = 5(\frac{\pi}{6}) \cos \frac{\pi}{6}t$
    When t = 1 s, $v = 5\left(\frac{\pi}{6}\right) \cos \left(\frac{\pi}{6}\right)$ = 2.3 m s^{-1}

12. C: Increased damping: Lower peak and lower resonant frequency.

13. D: Phase difference = $\frac{2\pi}{5.0}(3.0)$ rad = 3.8 rad

14. A: P at the amplitude, its speed = 0.

15. A: See figure.



16. D: Intensity level = 35 dB = $10 \lg \frac{I}{1.0 \times 10^{-11}}$
    $I = 3.16 \times 10^{-8}$ W m^{-2}

17. B: $F = 0$ at the equilibrium separation.

18. C: Plastic deformation, stress is not proportional to strain.

19. B: $\frac{1}{2}Mc^2 = \frac{3}{2}RT$, $c = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31)(373)}{0.034}}$ m s^{-1}
    $= 5.23 \times 10^2$ m s^{-1}

20. D: $c_1 = \sqrt{\frac{3RT_1}{M_1}} = c_2 = \sqrt{\frac{3RT_2}{M_2}}$
    $T_1 = \frac{M_1}{M_2}T_2 = \frac{32}{4}(300)$ K = 2400 K

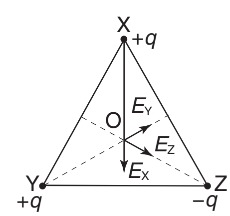
21. C: Adiabatic, $W = \Delta U = \frac{5}{2}R(\Delta T)$, $\Delta T = \frac{2W}{5R}$ = 2.41 K

22. D: $\Delta Q = 0$

23. D: Temperature gradient is small. A longer length is required to produce a sufficiently large temperature difference.

24. B: Temperature gradient at X is greater.

25. D:



The electric field strengths E_X, E_Y and E_Z at O due to the charges at X, Y and Z are of the same magnitude and in the directions shown in the figure. Therefore the resultant electric field at O is in the direction OZ.

26. B: Work done = electric potential energy of the system
    $= \frac{(+q)(-q)}{4\pi\varepsilon_0 r}$

27. C: $V = V_0 e^{-t/CR}$
    $\ln V = \ln V_0 - \frac{t}{CR}$

Gradient of graph = $\frac{-2}{20} = -\frac{1}{CR}$

$\left(\frac{1}{R} = \frac{1}{10\,\text{k}\Omega} + \frac{1}{40\,\text{k}\Omega} = \frac{5}{40\,\text{k}\Omega}\right)$

Capacitance, $C = (10)\left(\frac{5}{40 \times 10^3}\right)$ F $= 1.25 \times 10^{-3}$ F

28. C: $C_1 = \varepsilon_r C_0$, V remains the same because the battery remains connected. $E_0 = \frac{1}{2}C_0V^2$, $E_1 = \frac{1}{2}C_1V^2 = \varepsilon_r E_0$

29. D

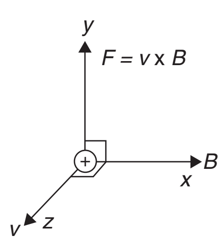
30. B: When $I = 0.23$ A, $V = \frac{0.23}{0.2}(4\text{ V})$

Power $= IV = (0.23)\left[\frac{0.23}{0.2}(4)\right]$ W $= 1.06$ W

31. A: Current in 2.0 Ω resistor,
$I = I_1 - I_2 = (2.56 - 1.64)$ A $= 0.92$ A
$V_{PQ} = IR = (0.92)(2.0)$ V $= 1.84$ V

32. A: P.d. across 40 cm $= I(100)$
P.d. across 44 cm $= I(100 + R)$,
$100 + R = \left(\frac{44}{40}\right)(100)\ \Omega$, $R = 10\ \Omega$

33. C:



34. C: $e\left(\frac{V_H}{d}\right) = Bev = Be\left(\frac{I}{nAe}\right)$
which is not in terms of the mass m of the charge carriers.

35. A: $E = -\frac{d\phi}{dt} = -\frac{0 - BA}{40\text{ ms}}$

Induced current, $I = \frac{E}{R} = \frac{(10.0)(0.10)^2}{(40 \times 10^{-3})(2.00)}$ A $= 1.25$ A

Clockwise direction: Apply Lenz's law.

36. C: Because of the back e.m.f., the current decreases.

37. C: $I = \frac{V}{X_L} = \frac{V}{2\pi fL} \propto \frac{1}{f}$

38. C: $I_{max} = \frac{V_{max}}{X_C} = \omega CV_{max} = (300)(200 \times 10^{-6})(5)$ A $= 0.30$ A

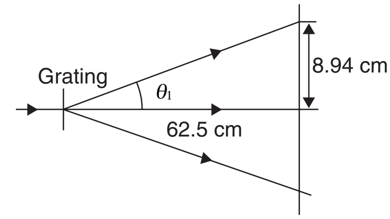
39. D: $V_P = 0$ V

40. C: $\boldsymbol{E} \times \boldsymbol{B}$ in the direction of propagation.

41. D

42. A: $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{u} + \frac{1}{v}$

43. B:



$$\lambda = d \sin\theta_1 = \frac{1}{2400 \times 10^2}\left(\frac{8.94}{\sqrt{8.94^2 + 62.5^2}}\right) \text{m} = 590 \text{ nm}$$

44. B: When the intensity is increased, the rate of photons incident on the cathode increases. Rate of emission of photoelectrons increases.

45. D: $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{(436 \times 10^{-9})(1.60 \times 10^{-19})}$ eV
$= 2.85$ eV $= E_5 - E_2$

46. C: $\lambda_{min} = \frac{hc}{eV}$

$\lambda'_{min} = \frac{hc}{e(V/2)} = 2\lambda_{min} = 8.0 \times 10^{-11}$ m

47. A: Laser photons are coherent and in phase.

48. C: Mass of C-12 atom $= 6m_p + 6m_n + 6m_e$

49. D: Initial number of atoms, $N_0 = \frac{2}{67}(6.02 \times 10^{23}) = 1.80 \times 10^{22}$

Initial activity, $A_0 = -\frac{dN}{dt} = \lambda N_0 = \left(\frac{\ln 2}{T_{\frac{1}{2}}}\right)N_0$

$t = 48\text{ h} = \frac{48}{78}T_{\frac{1}{2}} = 0.6154T_{\frac{1}{2}}$

Activity after 48 h, $A = \frac{A_0}{2^{0.6154}}$

$= \frac{1}{2^{0.6154}}\left(\frac{\ln 2}{78}\right)(1.80 \times 10^{22})\text{ s}^{-1} = 1.0 \times 10^{20}\text{ s}^{-1}$

50. A: ${}^{A}_{Z}\text{P} \rightarrow {}^{A-4}_{Z}\text{Q} + {}^{4}_{2}\text{He} + 2\,{}^{0}_{-1}\text{e}$

PAPER 2

Section A

1. Gain in translational K.E. + rotational K.E. = loss of P.E.

$$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = mgh$$

$$\frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\left(\frac{v}{r}\right)^2 = mgh$$

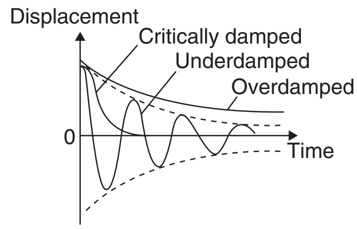
$$v^2\left(\frac{1}{2} + \frac{1}{4}\right) = gh$$

$$v = \sqrt{\frac{4}{3}gh}$$

$$= \sqrt{\frac{4}{3}(9.81)(1.0)}\text{ m s}^{-1}$$

$$= 3.6\text{ m s}^{-1}$$

2. (a)

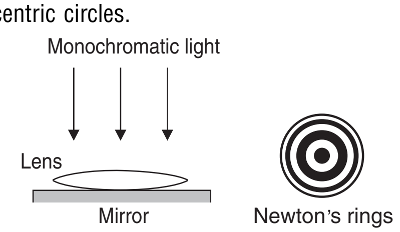


(b) • Resonance occurs when the amplitude of a forced oscillation is maximum.
• Resonance occurs when the frequency of the driver system equals the natural frequency of the system that is forced into oscillation.

3. (a) (i) The single-slit diffraction pattern as shown below is obtained.

(ii) The fringe separation increases.

(b) Place the lens on a mirror and allow monochromatic light to be incident on the lens.
If the lens surface is perfect, the interference pattern observed (Newton's rings) would be perfect concentric circles.



4. (a) Stress $= \dfrac{F}{A} = \dfrac{200}{\pi(5.0 \times 10^{-3})^2}$ N m^{-2}
$= 2.5 \times 10^6$ N m^{-2}

(b) Young's modulus, $E = \dfrac{F/A}{e/l}$

Change in length, $e = \dfrac{Fl}{EA}$

$= \dfrac{(200)(0.25)}{(9.7 \times 10^{10})\pi(5.0 \times 10^{-3})^2}$ m
$= 6.6 \times 10^{-6}$ m

5. (a) $\dfrac{1}{C} = \dfrac{1}{2.0} + \dfrac{1}{1.5}$, $C = 0.86\,\mu$F

(b) Charge stored in each capacitor, $Q = CV$
$= (0.86)(24)\,\mu$C
$= 21\,\mu$C

(c) With the dielectric
• Capacitance of each capacitor increases.
• Charge stored in each capacitor increases.

6. (a) Magnetic flux density, $B = \mu_0 nI$
Magnetic flux,
$\phi = NBA$
$= N(\mu_0 nI)A$
$= (4\pi \times 10^{-7})(1000 \times 2.0)\left(\dfrac{1000}{1 \times 10^{-2}}\right)(2.0)$
$\times (1.8 \times 10^{-4})$ weber
$= 0.090$ weber

(b) $\phi = LI$
$L = \dfrac{0.090}{2.0}$ H $= 0.045$ H

7. (a) Energy absorbed by the atom
= energy of photon – K.E. of electron
$= \dfrac{hc}{\lambda} - 180$ eV
$= \dfrac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{(0.110 \times 10^{-9})(1.60 \times 10^{-19})} - 180$ eV
$= 1.11 \times 10^4$ eV

(b) Kinetic energy, $\dfrac{1}{2}mv^2 = 180$ eV

Velocity of electron, $v = \sqrt{\dfrac{2(180)(1.60 \times 10^{-19})}{9.11 \times 10^{-31}}}$ m s^{-1}
$= 7.95 \times 10^6$ m s^{-1}

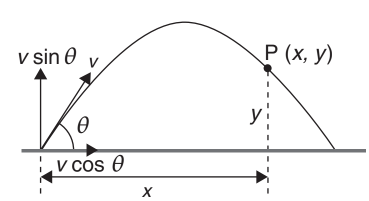
8. (a) Using the principle of conservation of linear momentum,
$M_{Li}V_{Li} + M_{He}V_{He} = 0$

Velocity of lithium atom, $V_{Li} = -\left(\dfrac{M_{He}}{M_{Li}}\right)V_{He}$
$= -\left(\dfrac{4.0026}{7.0160}\right)(9.10 \times 10^6)$ m s^{-1}
$= -5.192 \times 10^6$ m s^{-1}
Kinetic energy of lithium atom
$= \dfrac{1}{2}M_{Li}(V_{Li})^2$
$= \dfrac{1}{2}(7.0160 \times 1.66 \times 10^{-27})(5.192 \times 10^6)^2$ J
$= 1.57 \times 10^{-13}$ J

(b) Total mass before reaction = 1.0087 u + 10.0130 u
= 11.0217 u
Total mass after reaction = 7.0160 u + 4.0026 u
= 11.0186 u
Reaction energy,
$E = (\Delta m)c^2$
$= (11.0217 - 11.0186)(1.66 \times 10^{-27})(3.00 \times 10^8)^2$ J
$= 4.63 \times 10^{-13}$ J

Section B

9. (a)



When the object is at P,
• horizontal displacement, $x = (v \cos\theta)t$,
$t = \dfrac{x}{v \cos\theta}$
• vertical displacement, $y = (v \sin\theta)t - \dfrac{1}{2}gt^2$
$= (v \sin\theta)\left(\dfrac{x}{v \cos\theta}\right) - \dfrac{1}{2}g\left(\dfrac{x}{v \cos\theta}\right)^2$
$= x \tan\theta - \dfrac{gx^2}{2v^2 \cos^2\theta}$

(b) (i) Consider vertical component of motion of the bullet

$u = 0$, $a = g$, $s = 15$ m

Using $s = ut + \frac{1}{2}at^2$, $15 = 0 + \frac{1}{2}(9.81)t^2$

Time taken, $t = \sqrt{\frac{2(15)}{9.81}}$ s $= 1.7$ s

(ii) Distance of the jeep from the security post $= (700 - 1.7 \times 10)$ m $= 683$ m

(iii) Horizontal distance travelled by the bullet,

$v(1.7) = 683$ m

Speed, $v = 402$ m s^{-1}

(iv) Vertical component of the bullet's velocity,

$v_y = 0 + (9.81)(1.7)$

$= 16.7$ m s^{-1}

Horizontal component of velocity,

$v_x = 402$ m s^{-1}

Speed $= \sqrt{v_x^2 + v_y^2}$

$= \sqrt{402^2 + 16.7^2}$ m s^{-1}

$= 402.3$ m s^{-1}

Direction of velocity is at an angle

$\tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{16.7}{402.3}\right)$

$= 2.4°$ to the horizontal

10. (a) Doppler effect is the apparent change in the frequency of sound heard by an observer when there is relative motion between the source of sound and the observer.

(b) Comparing $y = (2.5 \times 10^{-5}) \sin 2\pi(500t - 1.4x)$

with $y = A \sin\left(2\pi ft - \frac{2\pi}{\lambda}x\right)$,

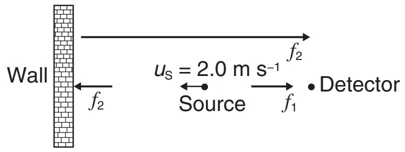
frequency, $f = 500$ Hz, $\lambda = \frac{1}{1.4}$ m

Speed of sound wave, $v = f\lambda$

$= (500)\left(\frac{1}{1.4}\right)$ m s^{-1}

$= 357$ m s^{-1}

(c) (i)



The source is moving away from the detector.

Frequency detected by the detector,

$f_1 = \left(\frac{v}{v + u_s}\right)f$

$= \left(\frac{360}{360 + 2.0}\right)500$ Hz

$= 497$ Hz

The source is approaching the wall.

Frequency reflected by the wall

= frequency incident on the wall, f_2

$f_2 = \left(\frac{v}{v - u_s}\right)f$

$= \left(\frac{360}{360 - 2.0}\right)500$ Hz

$= 503$ Hz

This frequency of 503 Hz is also detected by the detector.

(ii) Beat frequency $= f_2 - f_1$

$= (503 - 497)$ Hz $= 6$ Hz

(iii) $\frac{1}{\lambda_2} = \frac{f_2}{v} = \frac{503}{360} = 1.4$

Equation of the reflected wave is

$y = (2.5 \times 10^{-5}) \sin 2\pi(503t + 1.4x)$

(iv) Intensity is directly proportional to (amplitude)^2.

Since the approaching wave and the reflected wave have the same amplitude,

$\frac{\text{intensity of approaching wave}}{\text{intensity of reflected wave}} = 1$

11. (a) At A, $pV = nRT_A$

$T_A = \frac{(3 \times 10^5)(2.0 \times 10^{-3})}{(0.2)(8.31)}$ K $= 361$ K

At B, $T_B = T_A = 361$ K

B to C, p = constant, $V_C \propto T_C$, and $V_B \propto T_B$

$T_C = \left(\frac{V_C}{V_B}\right)T_B$

$= \left(\frac{2.0 \times 10^{-3}}{12.0 \times 10^{-3}}\right)361$ K

$= 60.2$ K

(b) From A to B, work done by the gas, $W_1 = nRT_A \ln\left(\frac{V_B}{V_A}\right)$

$= (0.2)(8.31)(361) \ln\left(\frac{12.0 \times 10^{-3}}{2.0 \times 10^{-3}}\right) = 1075$ J

Pressure at B, $p_B = \frac{p_A V_A}{V_B}$

$= \frac{(3 \times 10^5)(2.0 \times 10^{-3})}{12.0 \times 10^{-3}}$ Pa $= 5.0 \times 10^4$ Pa

From B to C, work done on the gas,

$W_2 = (5.0 \times 10^4)(12.0 - 2.0) \times 10^{-3}$ J $= 500$ J

Net work done by the gas $= (1075 - 500)$ J $= 575$ J

(c) From A to B, isothermal expansion, $\Delta U = 0$.

From $\Delta Q = \Delta U + W$,

heat absorbed, $\Delta Q_1 = W_1 = 1075$ J

From B to C, $\Delta Q_2 = nC_p(\Delta T)_2$ $\left(C_P = \frac{5}{2}R\right)$

$= (0.20)(\frac{5}{2})(8.31)(60.2 - 361)$ J $= -1250$ J

From C to A, V = constant, $\Delta Q_3 = nC_V(\Delta T)_3$

$= (0.2)\left(\frac{3}{2} \times 8.31\right)(361 - 60.2)$ J $= 750$ J

Net heat absorbed $= (1075 - 1250 + 750)$ J $= 575$ J

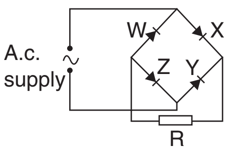
12. (a) (i) $X_C = \frac{1}{\omega C}$ $(\omega = 120\pi)$

$= \frac{1}{(120\pi)(0.3 \times 10^{-6})}$ $\Omega = 8.8 \times 10^3\ \Omega$

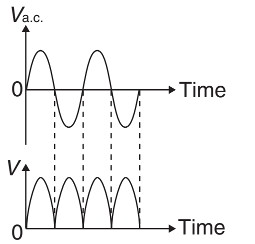
(ii) $I_{rms} = \frac{V_{rms}}{X_C}$ $\left(V_{rms} = \frac{240}{\sqrt{2}}\text{ V}\right)$

$= \frac{240}{\sqrt{2} \times (8.8 \times 10^3)}$ A $= 0.019$ A

(b) (i) A full-wave rectifier that consists of four diodes W, X, Y and Z is as shown below.



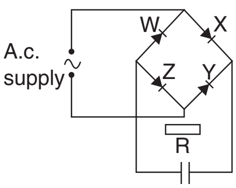
Full-wave rectifier



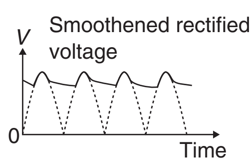
Full-wave rectified voltage

During the first half cycle of the a.c. voltage, current flows through X, R and Z. During the second half cycle, current flows through Y, R and W. In both the half-cycles, current flows in the same direction through R. Therefore, the voltage across the resistor R is full-wave rectified as shown.

(ii)



Capacitor C



The rectified voltage is smoothened by connecting a capacitor C in parallel with the load R as shown in the circuit. During the first half cycle, the capacitor C is charged until the peak voltage. Current stops flowing from the a.c. supply, and the capacitor discharges until the potential difference across the capacitor is less than the voltage of the a.c. supply. Current again flows from the a.c. supply until the capacitor is charged to the peak voltage again. The process is then repeated. The voltage V across the load R varies with time as shown in the graph.

13. (a) Bohr's postulates

- An electron can only orbit the nucleus in discrete allowed orbits such that

  angular momentum of the electron $= n\left(\dfrac{h}{2\pi}\right)$

  h is Planck constant, and $n = 1, 2, 3, \ldots$
- When an electron drops from a higher energy level E_2 to a lower energy level E_1, the difference in energy of the electron is radiated as a photon of frequency f.

$$E_2 - E_1 = hf$$

(b) From the first postulate of Bohr,

- angular momentum, $(mvr) = n\left(\dfrac{h}{2\pi}\right)$

$$m^2v^2r^2 = \frac{n^2h^2}{4\pi^2} \quad (1)$$

- centripetal force, $\dfrac{mv^2}{r} = \dfrac{e^2}{4\pi\varepsilon_0 r^2}$

$$v^2 = \frac{e^2}{4\pi\varepsilon_0 mr} \quad (2)$$

From (1) and (2), $m^2\left(\dfrac{e^2}{4\pi\varepsilon_0 mr}\right)r^2 = \dfrac{n^2h^2}{4\pi^2}$

Radius of the n^{th} orbit, $r = \dfrac{\varepsilon_0 n^2h^2}{\pi me^2}$

(c) (i) Kinetic energy, $\dfrac{1}{2}mv^2 = 8.64 \times 10^{-20}$ J

Speed of electron, $v = \sqrt{\dfrac{2(8.64 \times 10^{-20})}{9.11 \times 10^{-31}}}$ m s^{-1}

$= 4.36 \times 10^5$ m s^{-1}

(ii) Total energy of the electron in the n^{th} orbit, $E_n = -K$, the kinetic energy

Also, $E_n = -\dfrac{13.6}{n^2}$ eV

Therefore, $-\dfrac{13.6}{n^2}$ eV $= -8.64 \times 10^{-20}$ J

$n = \sqrt{\dfrac{(13.6)(1.60 \times 10^{-19})}{8.64 \times 10^{-20}}} = 5$

Allowed orbit $n = 5$

(iii) From $(mvr) = n\left(\dfrac{h}{2\pi}\right)$

Radius of orbit, $r = \dfrac{nh}{2\pi mv}$

$= \dfrac{5(6.63 \times 10^{-34})}{2\pi(9.11 \times 10^{-31})(4.36 \times 10^5)}$ m

$= 1.33 \times 10^{-9}$ m

14. (a) (i) ${}^4_2\alpha + {}^9_4\text{Be} \rightarrow {}^{12}_6\text{C} + {}^1_0\text{X}$

(ii) α-particle: Nucleus of helium.
${}^1_0$X: Neutron

(iii) X or neutron
- is not charged.
- does not cause ionisation.

(b) Energy equivalent of 1 u, $E = mc^2$

$= (1.66 \times 10^{-27})(3.00 \times 10^8)^2$ J

$= \dfrac{(1.66 \times 10^{-27})(3.00 \times 10^8)^2}{(1.60 \times 10^{-19})10^6}$ MeV

$= 934$ MeV

(c) $\dfrac{mv^2}{r} = qvB$

$m = \left(\dfrac{qB}{v}\right)r$

Assumption: Ions of the element and ions of C-12 have the same charge, then $m \propto r$.
Hence mass number, $A \propto r$
For X, $A_X \propto 26.2$ cm
For C-12, $12 \propto 22.4$ cm

Mass number, $A_X = \dfrac{26.2}{22.4}(12) = 14$

The element is nitrogen, N.